

Fig. 1

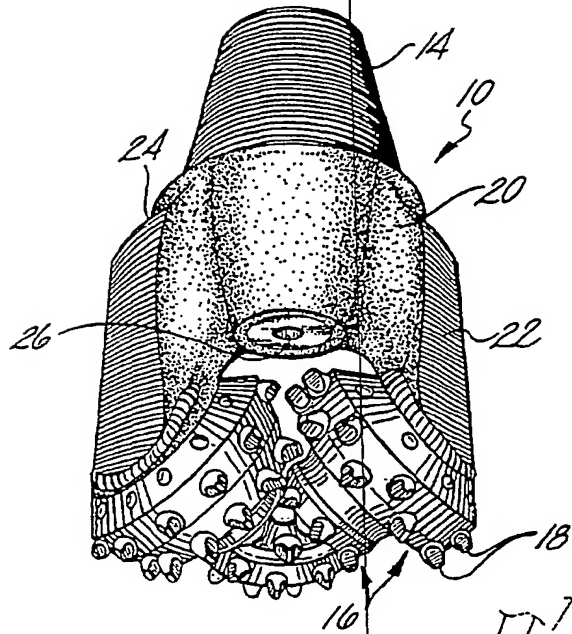


Fig. 3

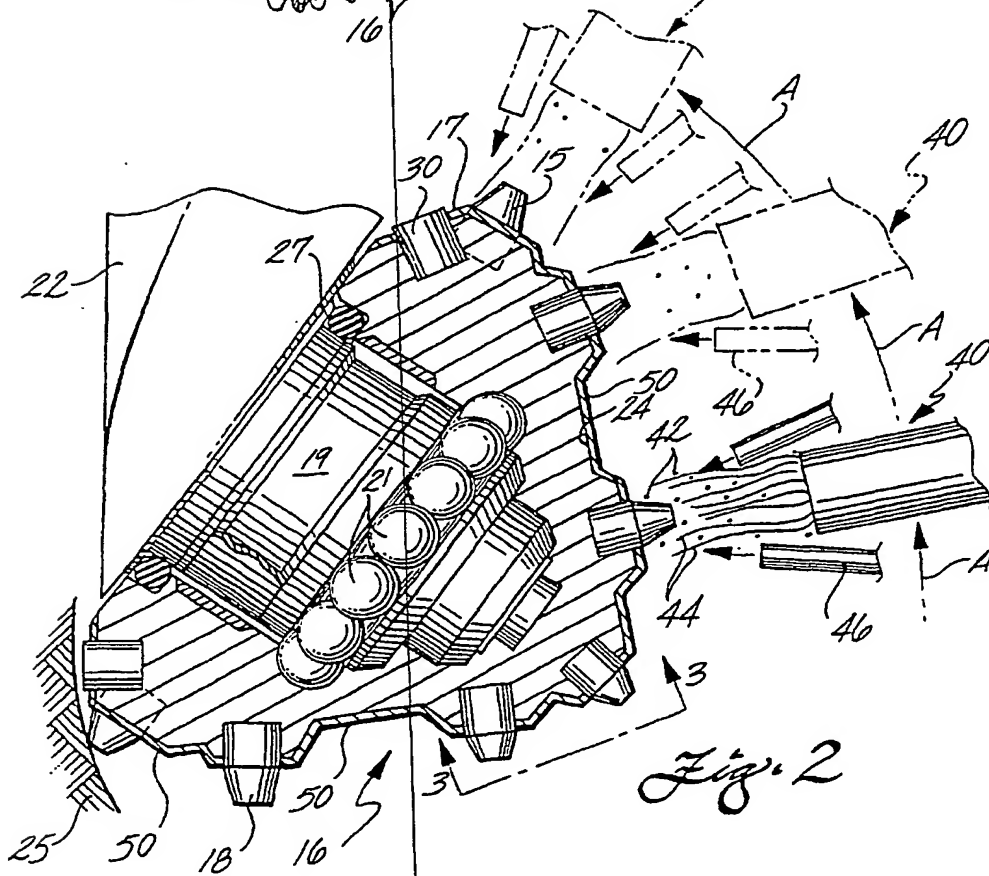
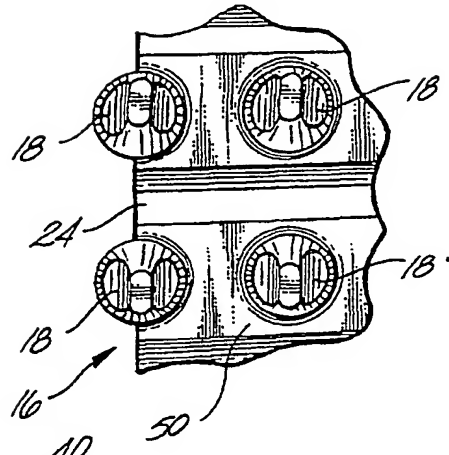


Fig. 2

1

5

10

HARDFACING FOR ROCK DRILLING BITS

15 This invention relates to hardfacing of metallic surfaces of rock bit components such as rotary cones, rock bit legs supporting the cones and the exposed surfaces surrounding the cutters mounted within the face of a drag type rock bit.

20 More particularly, this invention relates to the application of a hardfacing coating to the exposed surfaces of steel rotary cones and their supporting legs of rotary cone rock bits. The hardfacing coating also has an application for the cutting face surrounding diamond cutters mounted within the face of diamond drag rock bits and the like.

25 Hardfacing of rock drilling bit cones for the purpose of inhibiting cone erosion and wear during known harsh rock drilling conditions has been done before with varying degrees of success.

30 For example, U.S. Patent Numbers 4,708,752 and 4,781,770 teach the use of lasers to either harden the surface of the rotary cones of a rock bit or entrain a stream of hardfacing material into the laser beam to apply a layer of hardfacing material to the surface of the rotary cones. Both of the foregoing patents are
35 incorporated herein by reference.

U.S. Patent No. 4,685,359 describes a method of manufacturing a steel bodied bit in which a hardfacing of

1 a highly conformable metal cloth containing hard, wear
resistant particles is applied to rock bit faces and to
the interior of nozzle openings and the like. The cloth
known as "CONFORMA CLAD" manufactured by Imperial Clevite,
5 Inc. of Salem, Indiana must first be cut to shape to fit
the component to be hardfaced prior to brazing the cloth
to the workpiece; a time consuming and difficult process.

There is a disadvantage in foregoing method in that
the cloth material, when it is metallurgically attached to
10 the workpiece in a furnace, changes the physical
properties of the base material to the detriment of the
finished product.

Thus, an improved method of hardfacing of rock bit
cones and the like is disclosed that incorporates advanced
15 hardfacing materials and application methods.

A rock bit for drilling boreholes in an earthen
formation has at least some of its surfaces to be exposed
20 to the earthen formation hardfaced to resist erosion while
performing in the earthen formation. The hardfacing
comprises a layer of hard particles thermal sprayed onto
the surfaces of the rock bit. Preferably, the particles
comprise a metal carbide with a metal binder wherein the
25 coating has a hardness of at least 900 Kg/mm² Vickers
Hardness Number.

Preferably, the layer of hard particles is thermal
sprayed onto the surfaces of the rock bit at a velocity in
excess of 600 m/sec. The layer of hard particles has a
30 tensile bond strength in excess of 1400 kg/cm² that
results in an increase of the strain to fracture of the
rock bit surfaces through residual compressive stress.

The preferred method of applying the coating is by
way of a detonation gun process to apply hardfacing
35 material to rock bit components. Low temperature
application of the coating maintains residual stress
retaining tungsten carbide inserts interference fitted

1 within sockets formed in a rock bit cone surface. The
bombardment of the insert cutters during the detonation
gun application of the hardfacing material enables the
inserts to withstand higher compressive loads under
5 operating conditions.

Hydrogen embrittlement is minimized by application of
tungsten carbide cermet utilizing the detonation-gun
process. Hydrogen embrittlement is a process whereby
there is an invasion of the hydrogen ion into the highly
10 stressed carburized steel. A detonation gun is utilized
to apply a tungsten carbide based powder at a very high
velocity on a substrate such as a steel cone for a rotary
cone rock bit. Prior to the detonation-gun process, the
surface of the cones of a rock bit is preferably grit
15 blasted and degreased prior to coating. Grit blasting
roughens the surfaces and renders it slightly uneven which
leads to better bonding of the coating to the cone
surfaces. The maximum instantaneous surface temperature
on the cone shell while applying the coating is maintained
20 as low as about 200°C by, for example, impinging a stream
of liquid carbon-dioxide or other refrigerant fluid unto
the cone. Other mixtures of fluids, such as nitrogen,
could be used for improved heat dissipation. The
thickness of the coating is between 0.125 and 0.5 mm on
25 the cone shell. The coating thickness could vary
depending on the substrate and particle materials,
substrate geometry and application.

An unexpected benefit of the detonation gun process
is the alleviation of cone cracking by the inducement of
30 compressive residual stresses to the cone surfaces. The
detonation-gun process is especially useful in alleviating
those cracks that occur between tungsten carbide inserts
pressed into the cones that had, heretofore, plagued the
rock bit industry.

35

1

The above noted features and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings wherein:

5

FIGURE 1 is a perspective view of a typical three cone rock bit;

FIGURE 2 is a cross-section of one of the rotary cones undergoing the hardfacing application process; and

10

FIGURE 3 is a view taken through 3-3 of Figure 2 illustrating a portion of the hardfaced surface of the cone adjacent to each of the tungsten carbide inserts retained therein.

15

Boreholes are commonly drilled with rock bits having rotary cones with cemented carbide inserts interference fitted within sockets formed in the cones. A typical rock bit generally designated as 10 has a steel body 20 with threads 14 formed at an upper end and three depending legs 22 at a lower end. Three cutter cones generally designated as 16 are rotatably mounted on the three legs 22 at the lower end of the bit body 20. A plurality of, for example, cemented tungsten carbide inserts 18 are press-fitted or interference fitted into insert sockets formed in the cones 16. Lubricant is provided to the journals 19 (Fig. 2) on which the cones are mounted from each of three grease reservoirs 24 in the body 20.

20

25

When the rock bit is employed, it is threaded unto the lower end of a drill string and lowered into a well or borehole (not shown). The bit is rotated by a rig rotary table with the carbide inserts in the cone engaging the bottom of the borehole 25 (fig. 2). As the bit rotates, the cones 16 rotate on the bearing journals 19 cantilevered from the body and essentially roll around the bottom of the borehole 25. The weight on the bit is applied to the rock formation by the inserts 18 and the

30

35

1 rock is thereby crushed and chipped by the inserts. A
drilling fluid is pumped down the drill string to the
bottom of the hole 25 and ejected from the bit through
nozzles 26. The drilling fluid then travels up the
5 annulus formed between the exterior of the drill pipe and
the borehole wall carrying with it the rock chip detritus.
In addition the drilling fluid serves to cool and clean
the cutting end of the bit as it works in the borehole.

With reference now to Figure 2, the lower portion of
10 the leg 22 supports a journal bearing 19 by a plurality of
cone retention balls 21 confined by a pair of opposing
ball races formed in the journal and the cone. The cone
includes an annular heel row 17 positioned between the
15 gage row inserts 15 and bearing cavity 27 formed in cone
16. A multiplicity of protruding heel row insert cutters
30 are about equidistantly spaced around the heel row 17.
The protruding inserts 30 and the gage row inserts 15 co-
act to primarily cut the gage diameter of the borehole.
The multiplicity of remaining inserts in concentric rows
20 crush and chip the earthen formation as heretofore
described.

Much of the erosion of the cones typically occurs
between the gage row and the heel row inserts 15 and 30.
As heretofore described, this type of erosion may result
25 in damage to or loss of the inserts and cone cracking,
particularly between the inserts. In highly erosive
environments, the whole of the cone body is subjected to
severe erosion and corrosion.

A layer of hardfacing (hard particles) or coating 50
30 is thermal sprayed unto a rock bit surface and the hard
particles are selected from the group consisting of a
metal carbide with a metal or metal alloy wherein the
coating has a hardness of at least 900 Kg/mm² Vickers
Hardness Number (VHN).

35 The hardfacing coating 50 on cone 16 illustrated in
Figures 2 and 3 is preferably applied by a thermal spray
method. The thermal spray method shown in schematic form

1 in Fig. 2 and generally designated as 40 is preferably
applied by a detonation spraying apparatus manufactured by
Praxair Surface Technologies, Inc., Indianapolis, Indiana
and is called, the SUPER D-GUN (trademark) process. The
5 foregoing process heats fine powders such as tungsten
carbide to near their melting points and projects them at
extremely high velocities against the surface to be coated
(in the present example, the surface 24 of cone 16).
Particle velocities frequently exceed 600 m/sec.
10 Impingement of the entrained tungsten carbide or other
desirable mixture of hard particles 42 into surface 24 of
the steel bodied cone 16 results in a substantially
metallurgical bond that is unparalleled in the industry.
The layer of hard particles has a tensile bond
15 strength in excess of 1400 kg/cm² that results in an
increase of the strain to fracture of the rock bit
surfaces through residual compressive stress. The
residual compressive stress substantially increases the
strain-to-fracture of the coatings 50 mechanically bonded
20 to the surface 24 of cone 16.
Typically, the coating thicknesses range from about
0.125 to 0.5 mm. on the cones 16 and the hardness ranges
around 1100 Kg/mm² (VHN).
The SUPER D-GUN apparatus 40 shown in Figure 2 in
25 schematic form is preferably aligned 90 degrees to the
surface 24 of the cone 16. The nozzle of the apparatus 40
emits rapid pulses of hot gases 44 at very high velocities
that entrains, for example, powdered tungsten carbide or
tungsten carbide composite 42 therein. A fluid substance
30 such as liquid carbon dioxide 46 cools the cone during the
thermal spray process thereby preventing the cones from
heating above about 200°C. The substrate temperature can
be controlled by adjusting the coolant velocity and
geometry. This method of controlling the temperature of
35 the cones prevents degradation of the interference fit of
the inserts retained within sockets formed in the cone 16
during the thermal spray process.

1 The cones 16 are preferably cleaned and grit blasted
prior to the thermal spray process. This process results
in a slightly uneven cone surface 24 resulting in better
bonding of the tungsten carbide to the surface. The
5 surface roughness of the cone after grit blasting is
typically 200 to 300 microinches AA (5 to 8 micrometers).
While it is illustrated in Figure 2 with the thermal
spray apparatus 40 moving to different positions "A"
thereby maintaining the nozzle of the apparatus
10 approximately 90° to the surface 24; the reverse would be
more typical. The cone (separated from the journal 19) is
mounted to a moveable fixture (not shown) and the fixture
with attached cone is moved relative to the fixed thermal
spray apparatus 40.
15 Figure 3 depicts the finished hardfaced surface 50
that surrounds each of the inserts 18, the hardfacing
material (tungsten carbide) is tightly bound to the
surface 24 and immediately adjacent to each of the inserts
18.
20 Materials suitable for hard coating the exposed
surfaces of the rock bit cone include tungsten-chromium-
nickel-carbon composite, tungsten-chromium-cobalt-carbon
composite, tungsten carbide combined with either cobalt or
nickel, metal or ceramic.
25 The uniform application of the hardfacing material
through the use of the SUPER D-GUN process assures an
erosion resistant surface as well as a means to
essentially prevent cone cracking because of the residual
compressive stresses on the outer surface of the cones.
30 The detonation gun process comprises carefully
measured gases, usually consisting of oxygen and acetylene
that are fed into a barrel of the gun along with a charge
of fine tungsten carbide-based powder. The preferred
hardfacing powder is designated SDG 2040 and is developed
35 by Praxair Surface Technologies, Inc., Indianapolis, IN.
The SDG 2040 coating is mainly a mixture of tungsten
carbide with 15 wt % cobalt binder. The gas is ignited in

1 the D-GUN barrel and the resulting detonation wave heats
and accelerates the powder as it moves down the barrel.
The gas velocity and density are much higher than in a
5 a sufficient distance for it to be accelerated to its
extraordinary velocity. A pulse of inert nitrogen gas is
used to purge the barrel after each detonation. The
process is repeated many times per second. Each
detonation results in the deposition of a circle (pop) of
10 coating material a few micrometers thick on the surface 24
of the rock bit cone 16. The total coating, of course,
consists of several overlapping pops.

Precise, fully automated, pop placement results in a
very uniform coating thickness of the hardfacing material
15 50 and a relatively smooth, planar surface on the cones
16. Moreover, the SUPER D-GUN process minimizes hydrogen
embrittlement as heretofore described.

It will of course be realized that various
modifications can be made in the design and operation of
20 the present invention without departing from the spirit
thereof. For example, it is feasible to utilize various
ceramics or metals with the thermal spray detonation
process without departing from the scope of this
invention. Thus, while the principal preferred
25 construction and mode of operation of the invention have
been explained in what is now considered to represent its
best embodiments, which have been illustrated and
described, it should be understood that within the scope
of the appended claims, the invention may be practiced
30 otherwise than as specifically illustrated and described.

35

CLAIMS

1

1. A rock bit for drilling boreholes in an earthen formation, the rock bit having at least some of its surfaces to be exposed to the earthen formation hardfaced to resist erosion while performing in the earthen formation, the hardfacing comprising:

5

a layer of hard particles thermal sprayed onto the surfaces of the rock bit, the particles comprising a metal carbide with a metal binder wherein the coating has a hardness of at least 900 Kg/mm² Vickers Hardness Number.

10

2. A rock bit for drilling boreholes in an earthen formation, the rock bit having at least some of its surfaces to be exposed to the earthen formation hardfaced to resist erosion while performing in the earthen formation, the hardfacing comprising:

15

a layer of hard particles thermal sprayed onto the surfaces of the rock bit at a velocity in excess of 600 m/sec, the layer of hard particles having a tensile bond strength in excess of 1400 kg/cm² that results in an increase of the strain to fracture of the rock bit surfaces through residual compressive stress.

20

3. A method for hardfacing an exposed metal surface of a rock bit to render the surface of the rock bit more resistant to erosion while performing in an earthen formation comprising the steps of:

25

bombarding the surface with a thermal spray of entrained fine hard particles at a velocity in excess of 600 m/sec and coating the surfaces with a layer of such hard particles, the coating having a tensile bond strength in excess of 1400 kg/cm² that results in an increase of the strain to fracture of the rock bit surfaces through residual compressive stress, and a hardness of at least 900 Kg/mm² Vickers Hardness Number.

30

35

1 4. The method as set forth in Claim 3 wherein the
surfaces are bombarded with a thermal spray of hard
particles exiting from a nozzle formed by a detonation
5 gun, the nozzle being directed about ninety degrees to the
surface of the rock bit to be hardfaced with the layer of
hard particles.

 5. The method as set forth in either one of Claims
3 or 4 wherein the surfaces of the rock bit to be
10 hardfaced are rotary cutter cones of a rotary cone rock
bit.

 6. The method as set forth in Claim 5 wherein the
cutter cones contain a multiplicity of strategically
15 positioned tungsten carbide inserts retained within
sockets formed in the cones, the cones being bombarded by
the detonation gun with the inserts secured in the cones,
the hardfacing serving to inhibit erosion and corrosion
around the inserts thereby minimizing loss or destruction
20 of the inserts as the rock bit works in a borehole.

 7. The method as set forth in any one of Claims 3,
4 or 5 further comprising the step of cooling the surface
while applying the thermally sprayed coating.

25 8. The invention as set forth in any of the
preceding claims wherein the layer of hard particles is
selected from the group consisting of tungsten-chromium-
nickel-carbon composite and tungsten-chromium-cobalt-
30 carbon composite.

 9. The invention as set forth in any of the
preceding claims wherein the hard particles is a fine
powder of tungsten carbide combined with either cobalt or
35 nickel.

1 10. The invention as set forth in any of the
preceding claims wherein the hard particles comprise a
metal.

5 11. The invention as set forth in any of the
preceding claims wherein the hard particles comprise a
ceramic.

10 12. The invention as set forth in any of the
preceding claims wherein the thickness of the layer of
hard particles on the surface is between 0.125 and 0.5 mm.

15 13. The invention as set forth in any of the
preceding claims wherein the hardness of the layer of hard
particles is at least 900 Kg/mm² Vickers Hardness Number.

14. A rock bit substantially as described herein
with reference to the accompanying drawings.

20

25

30

35

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report)		Application number GB 9405340.2
Relevant Technical Fields (i) UK Cl (Ed.M) C7F (FGA, FGZ) (ii) Int Cl (Ed.5) C23C (4/06, 4/08, 4/10); E21B 10/46		Search Examiner P G BEDDOE
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications.		Date of completion of Search 29 JUNE 1994
(ii) ONLINE DATABASES: WPI, CLAIMS		Documents considered relevant following a search in respect of Claims :- 1 AND IN PART 8-14

Categories of documents

X: Document indicating lack of novelty or of inventive step.	P: Document published on or after the declared priority date but before the filing date of the present application.
Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.	E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A: Document indicating technological background and/or state of the art.	&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1475412	(BOSCH) see especially page 1 line 92 - page 2 line 4	1,9
X	GB 1291294	(RAMSEY) see especially page 3 lines 30-40	1,8,9
X	GB 1290986	(SULZER) see especially page 2 lines 22-23	1,8,9
X	GB 972414	(DEUTSCHE) see especially Example 6	1,9
X	GB 874463	(UNION CARBIDE) see especially page 2 lines 35-54	1,8,9
X	US 5141821	(STARCK) see especially column 2 lines 44-62	1
X	US 5126104	(GTE) see especially Example 1	1,9
X	US 4781770	(SMITH INTERNATIONAL) see especially column 7 lines 7-20	1,9
X	US 4173457	(ALLOYS) see especially column 2 lines 13-23; column 3 lines 1-30	1,9

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.